APPENDIX A

OCCUPATIONAL EXPOSURE POTENTIAL METHODOLOGY

The Occupational Exposure Potential (OEP), shown in Table 2.4-1, is a score derived from the product of three parameters qualitatively assigned by the Site Team. The parameters are: "Airborne Potential," "Constituent Level," and "Exposure Duration." Each parameter is assigned a numeric value according to prescribed criteria. The OEP score is then assigned according to the following scale:

Score	Likelihood
0	"No significant" occupational exposure potential
1	"Low" occupational exposure potential
2	"Moderate" occupational exposure potential
3	"High" occupational exposure potential

Airborne Potential is a subjective assignment of the likelihood of the contaminant to become airborne or concentrated in air. This judgement is largely based upon the form of the material and the nature of the particular operation. The associated numeric value is based on the following criteria:

Value	Likelihood
0	No likelihood of being airborne
1	Low airborne potential
2	Moderate airborne potential
3	High airborne potential

Constituent Level calculations for each of the various product streams were performed to estimate the additional dose presented by constituents present in irradiated uranium over that of the uranium alone. The DOE EH-3 team provided a standardized tool, in the form of an electronic spreadsheet, to perform the dose fraction calculations. The calculation and its technical basis are described in detail in the *Historical Generation and Flow of Recycled Uranium in the DOE Complex Project Plan*. An example of the output from the spreadsheet is shown in Figure A-1. To use the tool, the following information about the process stream being considered must be determined and input into the spreadsheet:

- chemical form
- level of enrichment in the ^{235}U isotope
- mass fraction of the constituents ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{237}Np, ^{241}Am, ^{236}U and ^{99}Tc

The required inputs were determined by assumption of estimates based on available analytical data, process knowledge, and engineering judgement, and calculations were performed for the streams of interest. These streams are depicted in Figure A-2 (for the feed plant) and Figure A-3 (for the gaseous diffusion plant). Assumptions for the calculations and the results are summarized in Table A-1.

The calculated fraction dose was then compared against criteria for assignment of the respective numeric value. This criteria is:

Value	Likelihood
0	Sum of constituents clearly below de minimis levels (clearly less than 10% additional dose)
1	Sum of constituents likely to cause up to 20% total dose
2	Sum of constituents likely to cause more than 20% but less than 50% total dose
3	Sum of constituents likely to cause 50% or more of total dose

Exposure Duration pertains to the time of worker exposure on the job. As such, it considers whether or not a particular activity was conducted infrequently or was one that was carried out on a daily basis. This parameter also was based upon a set of criteria to arrive at a numeric value. The criteria is:

Value	Likelihood
1	50 hours per year or less
2	More than 50 hours per year but less than 500 hours per year
3	50 or more hours per year

The results of this rating system for ORGDP activities are summarized in Table A-2, which was used to provide the OEP ratings presented in Table 2.4-1.

Chemical Forms of Uranium

Form	Code	Form	Code	Form	Code
U (metal)	1	UO3	0.83	UF6	0.68
UO2	0.88	UF4	0.76	UO2F2	0.77
U3O8	0.85	UCl4	0.63	UO2(NO3)2	0.6

	% U-235	U SpecAct uCi/g U	
U Enrichment (% U-235) =	0.64	3.60E-01	Ratio
	Code	DAC Value	Act to DAC
Chemical Form of U code =	0.83	3E-10	1.20E+09

SUM Constituent Act to DAC= 3.90E+08

Fraction Dose from Constituents = 0.3254

Constituent Data Units	uCi/g sample	uCi/g U	DAC Value	Act to DAC
Pu-238		0.00E+00	3.00E-12	0.00E+00
Pu-239		0.00E+00	2.00E-12	0.00E+00
Pu-240		0.00E+00	2.00E-12	0.00E+00
Np-237		0.00E+00	2.00E-12	0.00E+00
Am-241		0.00E+00	2.00E-12	0.00E+00
U-236		0.00E+00	3.00E-10	0.00E+00
Tc-99		0.00E+00	3.00E-07	0.00E+00

	uCi/g U	DAC Value	Act to DAC
Pu-238	3.76E-05	3.00E-12	1.25E+07
Pu-239	2.55E-04	2.00E-12	1.28E+08
Pu-240	5.99E-05	2.00E-12	3.00E+07
Np-237	3.67E-04	2.00E-12	1.83E+08
Am-241	0.00E+00	2.00E-12	0.00E+00
U-236	1.10E-02	3.00E-10	3.67E+07
Tc-99	1.33E-01	3.00E-07	4.42E+05

K-1131 Chemical Plant Stream 1 & 2

Assume

Pu ppb	4.4
Np ppb	520
Tc ppm	7.8
U-236 ppm	170

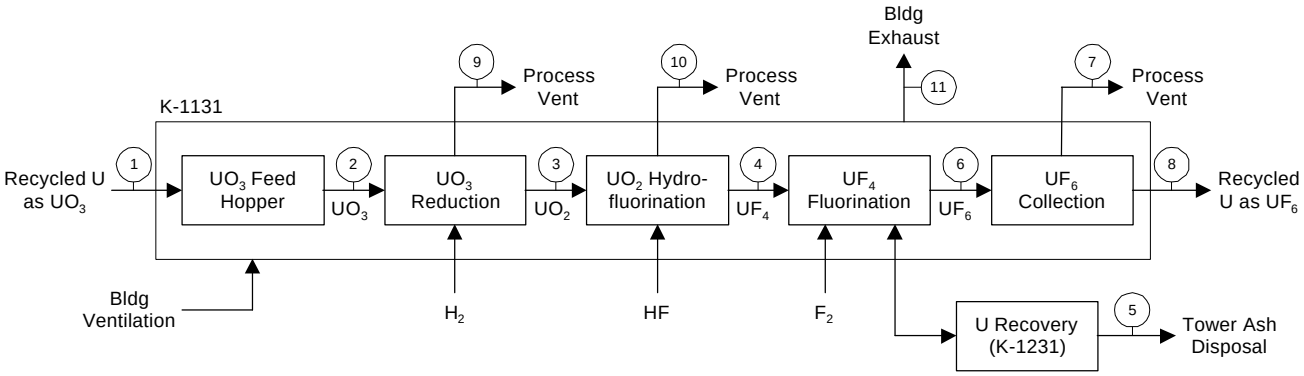
Assume UO3 @ .64 U-235

Assume Weapons Pu Dist

Pu-238	0.05
Pu-239	93.5
Pu-240	6
Pu-241	0.4
Pu-242	0.05

Figure A-1. Example Output of RU Dose Fraction Calculator.

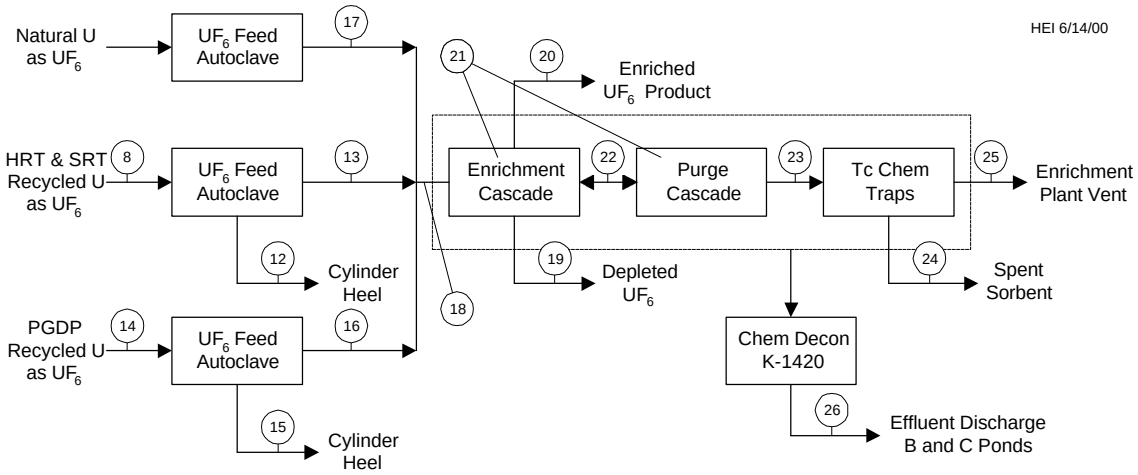
HEI 6/14/00



Stream Component	Stream Composition										
	1	2	3	4	5	6	7	8	9	10	11
U, kg	1000	1000	1000	1000	10	990	1	989	0.1	0.1	0.01
Pu, mg	4.4	4.4	4.4	4.4	~4.4	0.04	0	0.04	~0	~0	~0
Np, mg	520	520	520	520	130	390	~0	390	~0	~0	~0
Tc, g	7.8	7.8	7.8	7.8	0.4	7.4	0.2	7.2	0.001	0.001	~0
^{236}U, g	170	170	170	170	1	169	0.2	169	~0	~0	~0

Basis: 1 MTU feed, 1,200 kgs UO_3, 1,130 kgs UO_2, 1,320 kgs UF_4, 1,480 kgs UF_6

Fig. A-2. Historical Generation and Flow of RU in the DOE Complex, Distribution of RU Components in the K-1131 Chemical Plant.



Stream Component	Stream Composition[1,2]															
	8	12	13	14	15	16	17	18	19	20	21[3]	22	23	24	25	26[4]
U, kg	989	10	979	1840	10	1830	1430	4240	3670	565	1	100	0.1	0.01	0.1	1
Pu, mg	0.04	0.04	0.004	0	0	0	0	0.004	0	0	0.004	~0	0	0	0	0.002
Np, mg	390	260	130	trace	trace	~0	0	130	0	trace	130	~0	~0	trace	~0	65
Tc, g	7.2	0.7	6.5	3.6	0.4	3.2	0	9.7	0	1.0	7.5	8.7	1.2	1.0	0.2	7.5
^{236}U, g	169	1	168	0	0	200	0	368	145	223	0.1	10	0.01	0.001	0.01	0.1

1. Basis: 1 MTU RU entering K-1131 feed plant or 1,200 kgs UO_3
2. Trace = level of detection, 100 ppb U, 0.05 ppb Pu, 5 ppb Np, 10 ppb Tc
3. Stream representing cascade accumulation of feed components with time
4. Only during maintenance work involving converters and compressors taken from feed point (Pu, Np) and purge cascade (Tc)

Fig. A-3. Historical Generation and Flow of RU in the DOE Complex, Distribution of RU Components in the GDP.

Table A-1. Fraction Dose From Constituents For Process Streams

Process Stream Location (Refer To Flow Sheet)	Assumed Form	Assumed Assay (% U-235)	Assumed Constituent Level on U Basis	Fraction Dose From Constituents
1. K-1131 Chemical Plant Stream 1 & 2 (1) RU as UO3 to Feed Hopper (2) UO3 to UO3 Reduction	UO3	.64	520 ppb Np 4.4 ppb Pu 7.8 ppm Tc 170 ppm ^{236}U	0.3254
Same stream as above but Max Case Pu	UO3	.64	520 ppb Np 40 ppb Pu 7.8 ppm Tc 170 ppm ^{236}U	1.4718
2. K-1131 Chemical Plant Stream 3 UO2 to UO2 Hydrofluorination	UO2	.64	520 ppb Np 4.4 ppb Pu 7.8 ppm Tc 170 ppm ^{236}U	0.3254
3. K-1131 Chemical Plant Stream 4 UF4 to UF4 Fluorination	UF4	.64	520 ppb Np 4.4 ppb Pu 7.8 ppb Tc 170 ppm ^{236}U	0.3254
4. K-1131 Chemical Plant Stream 5 Tower Ash Disposal	UF4	.64	13,000 ppb Np 440 ppb Pu 40 ppm Tc 100 ppm ^{236}U	18.0084
Same stream as above but Max Case Pu	UF4	.64	13,000 ppb Np 4,000 ppb Pu 40 ppm Tc 100 ppm ^{236}U	132.6553
5. K-1131 Chemical Plant Stream 6 UF6 to UF6 Collection	UF6	.64	393.94 ppb Np 0.04 ppb Pu 7.47 ppm Tc 170.71 ppm ^{236}U	0.2654
6. K-1131 Chemical Plant Stream 7 UF6 to Process Vent	UF6	.64	0.00 ppb Np 0.00 ppb Pu 200 ppm Tc 200 ppm ^{236}U	0.0548
7. K-1131 Chemical Plant Stream 8 RU as UF6	UF6	.64	394.34 ppb Np 0.04 ppb Pu 7.28 ppm Tc 170.88 ppm ^{236}U	0.2657
8. K-1131 Chemical Plant Stream 9 UO3 Reduction to Process Vent	UO2	.64	0.00 ppb Np 0.00 ppb Pu 10 ppm Tc 0.0 ppm ^{236}U	0.0005
9. K-1131 Chemical Plant Stream 10 RU as UF6 UO2 Hydrofluorination to Process Vent	UF4	.64	0.00 ppb Np 0.00 ppb Pu 10 ppm Tc 0.0 ppm ^{236}U	0.0005
10. ORGDP Stream 12 UF6 Cylinder Heel	UF6	.64	26,000 ppb Np 4.00 ppb Pu 70 ppm Tc 100.00 ppm ^{236}U	15.5572
11. ORGDP Stream 13 Hanford & Savannah River UF6 Feed Autoclave to Cascade	UF6	.64	132.79 ppb Np 0.00 ppb Pu 6.64 ppm Tc 171.60 ppm ^{236}U	0.1097
12. ORGDP Stream 14 PGDP RU to UF6 Feed Autoclave	UF6	.65	5.00 ppb Np 0.00 ppb Pu 1.96 ppm Tc 0.00 ppm ^{236}U	0.0031

Table A-1. Fraction Dose From Constituents For Process Streams

Process Stream Location (Refer To Flow Sheet)	Assumed Form	Assumed Assay (% U-235)	Assumed Constituent Level on U Basis	Fraction Dose From Constituents
13. ORGDP Stream 15 PGDP UF6 Cylinder Heels	UF6	.65	5.00 ppb Np 0.00 ppb Pu 40 ppm Tc 0.00 ppm ^{236}U	0.0067
14. ORGDP Stream 16 PGDP UF_6 to Cascade	UF6	.65	0.00 ppb Np 0.00 ppb Pu 1.75 ppm Tc 109.29 ppm ^{236}U	0.0198
15. ORGDP Stream 18 UF6 to Cascade	UF6	.66	30.66 ppb Np 0.00 ppb Pu 2.29 ppm Tc 86.79 ppm ^{236}U	0.0339
16. ORGDP Stream 19 Depleted UF6	UF6	.30	0.00 ppb Np 0.00 ppb Pu 0.00 ppm Tc 39.51 ppm ^{236}U	0.0071
17. ORGDP Stream 20 Enriched UF6 Product	UF6	3.0	5.00 ppb Np 0.00 ppb Pu 1.77 ppm Tc 394.69 ppm ^{236}U	0.0170
18. ORGDP Stream 21 Cascade Accumulation Stream	UO2F2	1.0	130,000 ppb Np 4.00 ppb Pu 7,500 ppm Tc 100.00 ppm ^{236}U	35.5492
19. ORGDP Stream 22 Purge Cascade Stream	UF6	3.0	0.00 ppb Np 0.00 ppb Pu 87 ppm Tc 100.00 ppm ^{236}U	0.0060
20. ORGDP Stream 24 ^{99}Tc Chem Traps Spent Sorbent Stream	UF6	3.0	5.00 ppb Np 0.00 ppb Pu 100,000 ppm Tc 100.00 ppm ^{236}U	2.1696
21. K-1420 Stream 26 Chem Decon K-1420 to Effluent Discharge B & C Ponds Stream	UO2F2	1.0	2.00 ppb Np 0.02 ppb Pu 200 ppm Tc 100.00 ppm ^{236}U	0.2292
22. B & C Pond Sludge	UO2F2	0.7	2.00 ppb Np 0.02 ppb Pu 200.00 ppm Tc 100.00 ppm ^{236}U	0.2256

Weapons grade isotopic distribution assumed:

Pu-238	0.05
Pu-239	93.5
Pu-240	6.0
Pu-241	0.4
Pu-242	0.05

Table A-2. Occupational Exposure Potential Worksheet

Location	Activity	Constituent Level 0-3	Airborne Potential 0-3	Exposure Duration 1-3	Occupational Exposure Potential 0-27
	1. **Oxide Conversion**				
K-1131 K-1420	1A. Unpacking, feeding of UO_3 to process, operation and pulling samples	1	2	3	6 Moderate
K-1131 K-1420	1B. Collecting ash for uranium recovery and cleaning of tower filters	3	3	3	27 High
K-1231 K-1410	1C. U recovery from ash, processes included ash pulverizer	3	3	2	18 High
K-1131 K-1410	1D. Maintenance and repair of fluorination tower and associated equipment	3	3	2	18 High
	2. **Cascade Buildings and Operations**				
Cascade feed points	2A. Feeding UF_6 from cylinder to the cascade	2	2	1	4 Moderate
Cascade buildings	2B. Inadvertent releases of UF_6 within cascade buildings or from piping between cascade buildings	2	1	1	2 Moderate
Product withdrawal points	2C. Withdrawal of product from cascade into cylinders	0	2	1	0 No significant
Tails withdrawal points	2D. Withdrawal of tails from cascade into cylinders	0	2	1	0 No significant
Cascade purge locations	2E. Venting process gas to atmosphere from operating cascade through process stack	3	3	1	9 Moderate
Cascade feed points	2F. CIP/CUP and other work involving removal of converters, compressors, and valves associated with cascade feed points	3	3	1	9 Moderate
Cascade purge locations	2G. CIP/CUP and other work involving removal of converters and compressors, and valves associated with the purge cascade	3	3	1	9 Moderate
Cascade buildings	2H. CIP/CUP and other work involving equipment removal and maintenance activities other than near feed point or purge cascade	0	3	2	0 No significant
	3. **Recovery Operations**				
K-1410 K-1420	3A. Cleaning of heels from UF_6 cylinders	3	2	1	6 Moderate
K-1303 K-1410 K-1420	3B. Decontamination of equipment associated with feed point and recovery of uranium	3	3	1	9 Moderate
K-1303 K-1410 K-1420	3C. Decontamination of equipment associated with purge cascade and recovery of uranium	3	3	1	9 Moderate
K-1303 K-1410 K-1420	3D. Decontamination of equipment associated with other than near feed point or purge cascade	0	3	3	0 No significant
K-1037 K-1303 K-1410 K-1420 K-1421	3E. Uranium recovery from and/or processing of contaminated oils, cleaning solutions, and other wastes	1	1	3	3 Moderate

Table A-2. Occupational Exposure Potential Worksheet

Location	Activity	Constituent Level 0-3	Airborne Potential 0-3	Exposure Duration 1-3	Occupational Exposure Potential 0-27
K-770 Scrap Metal Yard	3F. Handling of scrap metal from equipment	1	1	1	1 Low
K-1407-B K-1407-C K-1419	3G. Removal, transfer, and/or storage of sludge from facility treating constituents concentrated in sludge	2	1	3	6 Moderate
RUBB Buildings	3H. Thermal drying/repackaging of pond sludge for offsite disposal	3	3	1	9 Moderate
Cascade buildings and associated piping	3I. Recovery of uranium deposits from process equipment associated with cascade feed points following shutdown of ORGDP	3	2	1	6 Moderate
Cascade buildings and associated piping	3J. Recovery of uranium deposits from process equipment associated with purge cascade following shutdown of ORGDP	3	2	1	6 Moderate
Cascade buildings and associated piping	3K. Recovery of uranium deposits from process equipment other than feed points and cascade purge following shutdown of ORGDP	0	2	2	0 No significant
K-1031 K-1410 K-1420	3L. Service cascade chemical traps	3	3	1	9 Moderate
	4. Analytical Labs				
Analytical laboratories K-1004A, B, C, D, J K-1006	4A. Analytical laboratory sampling	3	0	1	0 No significant